Closing the Water and Energy Budgets on Regional Scales

A GEWEX Radiation Panel Perspective

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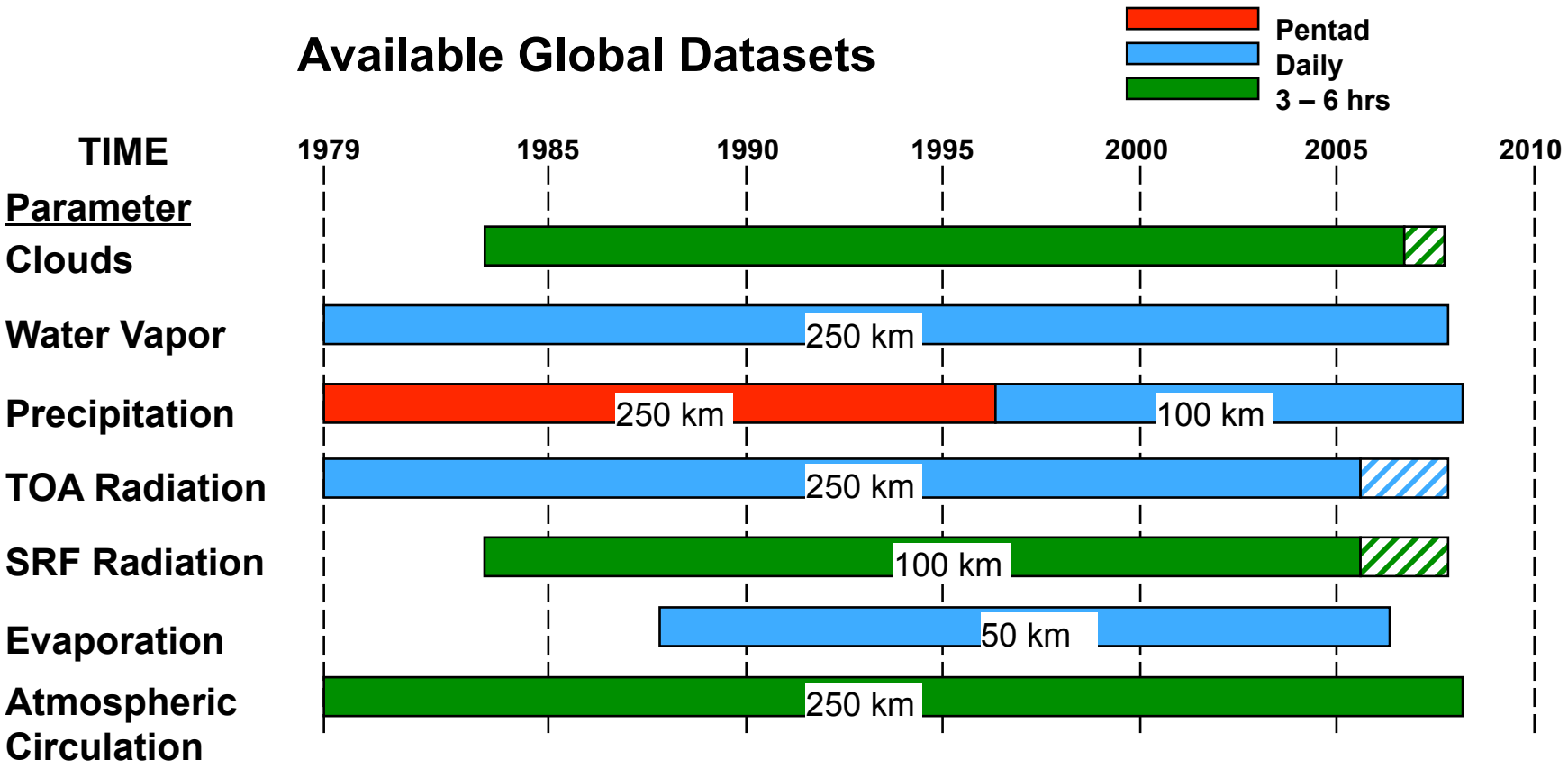
GEWEX/GRP Panels & Activities

- Clouds - IPCC
  - Cloud Assessment
- Water Vapor -
- Radiation - SRB
  - Surface reference observations - BSRN
  - TOA fluxes - CERES
  - Radiation Assessment
- Aerosols - GACP
  - Aerosol Assessment
- Precipitation - GPCP
  - Sfc gauge obs moved to CEOP - GPCC
  - First Assessment is published
- Turbulent Fluxes
  - SeaFlux
  - LandFLux

- *Radiative transfer - Model Intercomparisons - CIRC*
- *Radiative transfer model development - IR3D*

GRP Objective

GRP products consist of available satellite and in-situ observations and have generally undergone rigorous scrutiny and formal assessments over prolonged periods. GEWEX will strive to close the water and energy budgets on regional scales and fine enough time scales to elucidate feedback processes. Nominally 100km, 3-6 hr scales. ***Create a common product w. necessary W & E fields for easy access by the science community***

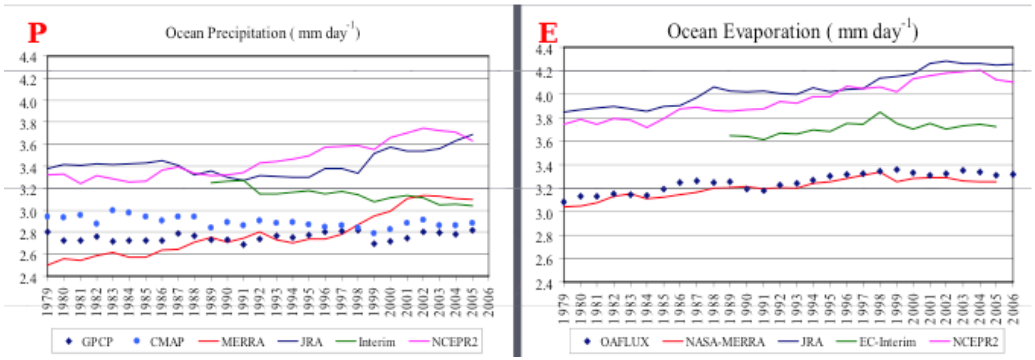


Water Vapor - GRP basis for discussion

- T, q profiles are needed to study 3D atmosphere and to use it as input for ISCCP, SRB and others, but no single source was available.
- Major obstacles were:
  - Old GEWEX NVAP data set was based on a concept that merged several sources of satellite and in situ data without caring too much on instrument characterization or intercalibration of satellites.
  - Operationally derived profile data sets, as used in ISSCP, were derived in real time and were not well intercalibrated.
  - Early NWP based reanalysis data sets suffered from inadequate data assimilation techniques that prohibited the full use of satellite observations, e.g., most of the observations are only used over oceans and under clear sky conditions.
  - Recent new reanalysis have much improved data assimilation techniques but exhibit artificial trends
- Old sounders need background information in the retrieval to be competitive with models.
- New sounders (AIRS, IASI) appear to outperform NWP models.
- Many comparisons between NWP reanalysis, satellite products and radiosonde and GPS data exist in the literature but an organized product assessment has not been done.
- Instrument characterisation and intercalibration is critical but difficult.

GRP outlook

- GSICS is tackling the calibration and intercalibration of current satellite data streams
- Data stewardship has gained traction for calibration and intercalibration of historical data.
- HIRS data is being reprocessed with uniform calibration
- NVAP activity is again active under NASA MEASURES program.
- Reanalyses getting better although artificial trends are problematic



Long term: Consider restarting a water vapor assessment. This should consider TPW, UTH and water vapor profiles separately over ocean and land.

Short term: Evaluate new HIRS product for use in combined data set

Precipitation: GPCP Version 3 Plan

Current (heritage) products (monthly, pentad, daily) to continue--at least to compare with new versions, but also to perhaps be used in calibration procedures. (Version 2.1 has "solved" RSS microwave issues) (will explore impact of using L1C data)

Tentative suite of Version 3 products (overlapping time resolutions)

3-hr [00Z, 03Z,….snapshot plus 3-hr total estimated for 00-03Z, 03-06Z, etc.] (0.25°) 50N-50S (possibly 60° in some areas; incomplete grids); 1998-present (will test TMPA, CMORPH)

Daily [00Z-00Z] (0.5°) global (1998-present; will use 3-hr product at low latitudes, current daily (1dd) product to complete globe; B1period [IR], (~1983-1997) PERSIANN for calibrated IR (50N-50S)

Pentad (sum of daily), with current pentad technique to complete globe.

Sub-monthly products forced to monthly--*this is meant to constrain total of 3-hr or daily estimates which may vary during period*

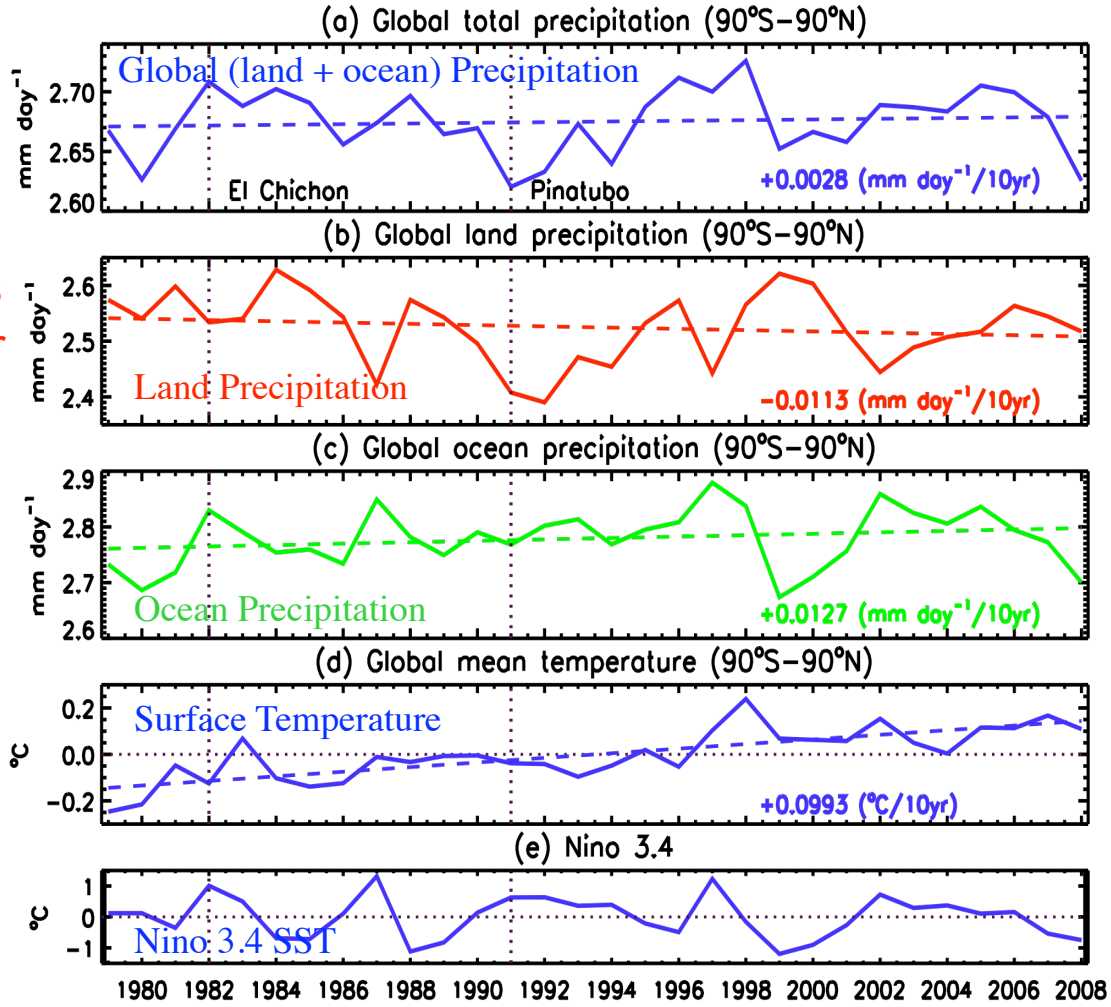
Monthly (target: 0.5°) global; 1979-present (pre-1987 period will use B1 supplemented by OPI.

(2 possible approaches for SSM/I period: 1 SSM/I and calibrated IR, or multiple SSM/I's with correction for diurnal--remember 0.5° spatial resolution)

Monitoring Global Precipitation with the Global Precipitation Climatology Project (GPCP)

Year 2008 Added to GPCP Record—now 30 years

- 2008 near record low global (land + ocean) precipitation; trend very near zero, despite global warming during period.
- Near compensation of ocean and land inter-annual variations leaves slight residual of warmer and wetter years during El Niños. 2008 was La Niña year.
- Peak temperature in 1998 associated with peak precipitation and El Niño; since '97-'98 surface temperature level and precipitation varies with ENSO.
- Temperature/precipitation relations on inter-annual and trend (climate change) scales one focus of NEWS study



Adler, Huffman, Gu

Radiation Budgets from SRB

Parameter	Ohmura & Gilgen (1993) *GEBA Surf. Obs.*		Kiehl and Trenberth (1997) ERBE/ CCM3		Zhang & Rossow (2004) *21-Year Mean (1984-2004)*		NASA/GEWEX SRB Release 3.0/2.5 LW (NASA LaRC) *23-Year Mean (July 1983 - June 2006)*			
							SW, LW		SW, LW QC	
	Flux	% F_0	Flux	% F_0	Flux	% F_0	Flux	% F_0	Flux	% F_0
SW Down	169.0	49.4	198	57.9	189.2	55.4	188.8	55.2	182.3	53.3
SW Net	142.0	41.6	168	49.2	165.9	48.5	166.7	48.8	159.7	46.7
LW Down	345	100.9	324	94.8	343.8	100.6	343.1	100.4	347.5	101.7
LW Net	-40.0	-11.7	-66	-19.3	-49.6	-14.5	-52.8	-15.4	-51.2	-15.0
Total Net	102.0	29.8	102	29.8	116.3	34.0	113.9	33.3	108.5	31.7
SW CRF	--	--	--	--	-53.0	-15.5	-58.7	-17.2	-60.9	-17.8
LW CRF	--	--	46	13.5	29.5	8.6	35.3	10.3	34.4	10.1
Total CRF	--	--	--	--	-23.5	-6.9	-23.4	-6.8	-26.5	-7.8

$S_0 = 1367\ W\ m^{-2}$; $(F_0 = S_0/4)$

Statistics of GEWEX RFA *Satellite* Data Comparison with BSRN Data

Data Set	Bias (Wm^{-2})	RMS (Wm^{-2})	ρ	σ (Wm^{-2})	N
Sat_DLR_ISIS_Ed001	-1.9211	15.7730	0.9859	15.6596	1978
Sat_FORTH_Ed01a	-14.1678	24.2317	0.9703	19.6637	1811
Sat_GEWEX_SRBGSW_Ed281	-7.2823	20.7451	0.9771	19.4299	1978
Sat_GEWEX_SRBQSW_Ed025	-0.7686	16.8880	0.9830	16.8747	1978
Sat_ISCCP_FD_Ed000_010	-1.5877	16.5076	0.9842	16.4352	1978
Sat_UMD_SRB_Ed033	7.6642	21.6148	0.9791	20.2155	1978

Statistics of GEWEX RFA *Reanalysis* Data Comparison with BSRN Data

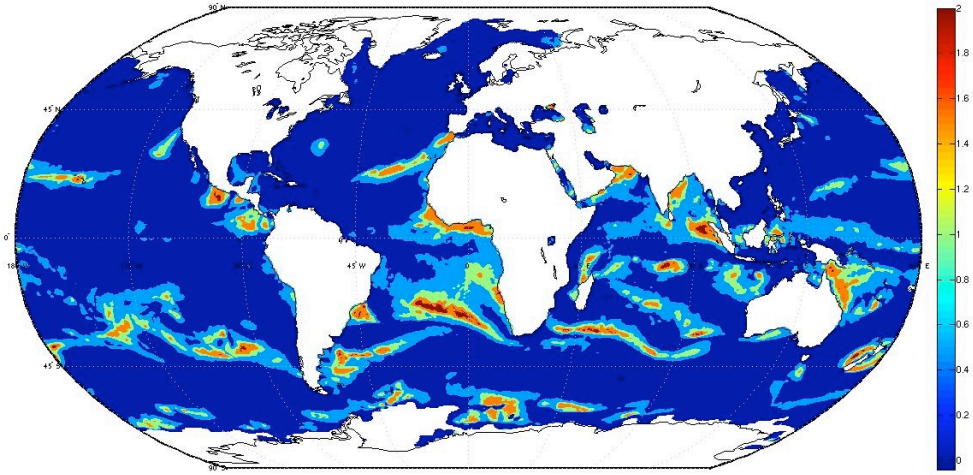
Data Set	Bias (Wm^{-2})	RMS (Wm^{-2})	ρ	σ (Wm^{-2})	N
Rea_ECMWF_ERA40_Ed001	-1.9805	17.1327	0.9842	17.0311	642
Rea_GFDLCM2.1_Ed001	-10.8181	26.5905	0.9672	24.3093	642
Rea_IPCC_AVERAGE_EdAR4	-16.3822	25.2508	0.9810	19.2302	642
Rea_IPCC_MEDIAN_EdAR4	0.3034	19.4605	0.9806	19.4733	642
Rea_NCEP_DOE_R2_Ed002	19.1322	33.9217	0.9631	28.0333	642

SeaFlux Progress

- Version 1.0 of climatological flux data set has been completed for years 1998 – 2005
- Next SeaFlux workshop will be in conjunction with US CLIVAR High Latitude Surface Flux Working Group (Boulder, March 17 – 19, 2010)
- All intercomparisons have been completed
  - Results are being shared with authors of other datasets
  - Final draft with approval from other authors by December
  - Aimed at BAMS/also in conjunction with JOFURO article

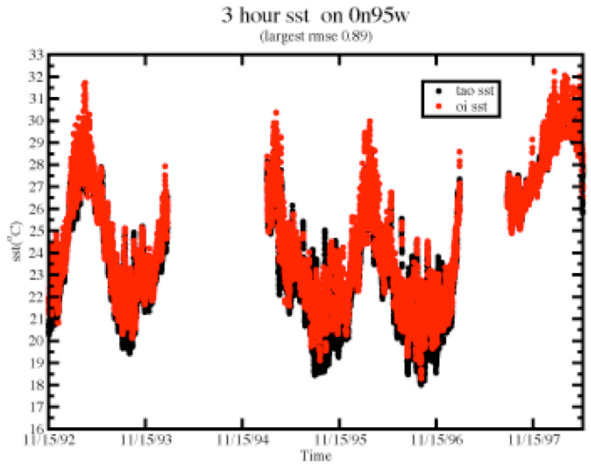
Version 1.0 of SST completed

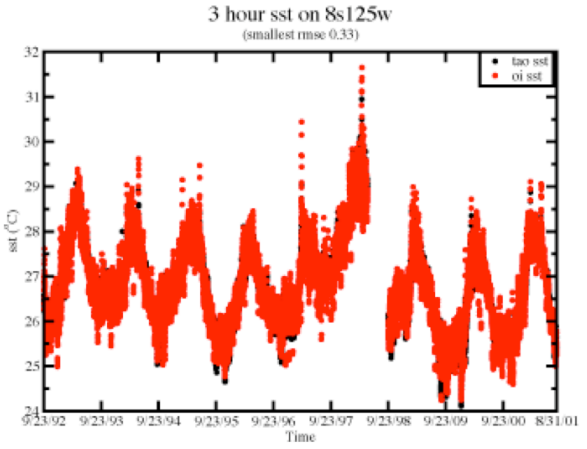
- Diurnal SST variability from Clayson and Curry algorithm
  - Uses SRB solar radiation
  - NOAA blended winds
- Pathfinder 5 for pre-dawn

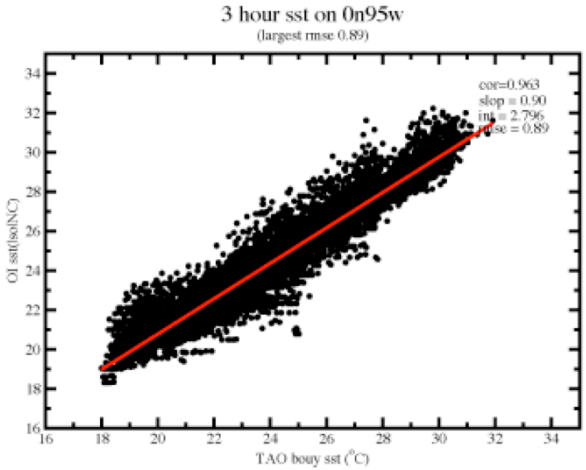


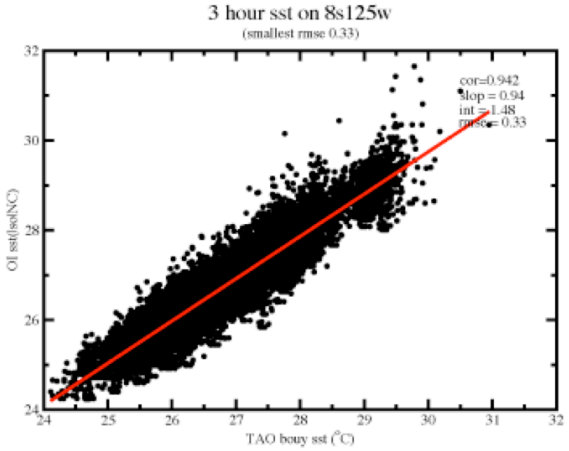
- 25-km resolution, 3-hourly
- Processed at FSU (Clayson, Roberts) and Georgia Tech (Chang, Curry) -- available on SEAFLUX website
- Version 2.0: include all available data from other times and appropriately adjust diurnal curve – anticipated completion is by end of 2009
- Plans for re-process: currently we are looking at ISCCP SSTs as the “base” SST instead of the Reynolds product; possibly including aerosol effects

Diurnal SST comparisons - TAO







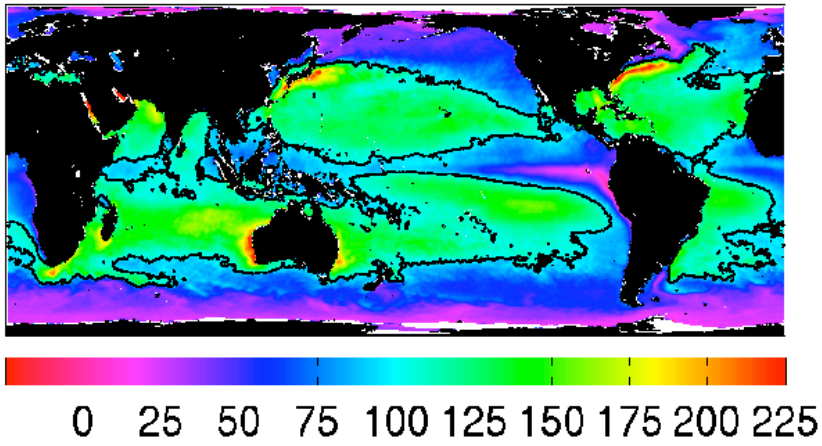


Bias: 0.2 °C, Rmse: 0.89 °C

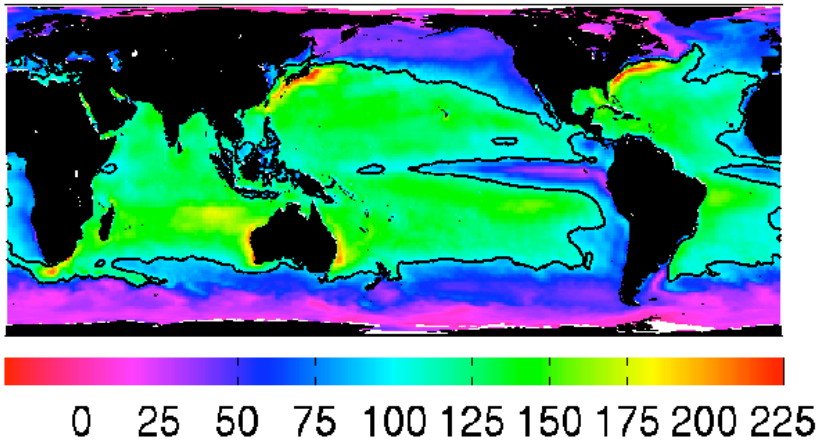
Bias: 0.05 °C, Rmse: 0.33 °C

1999 LH flux average

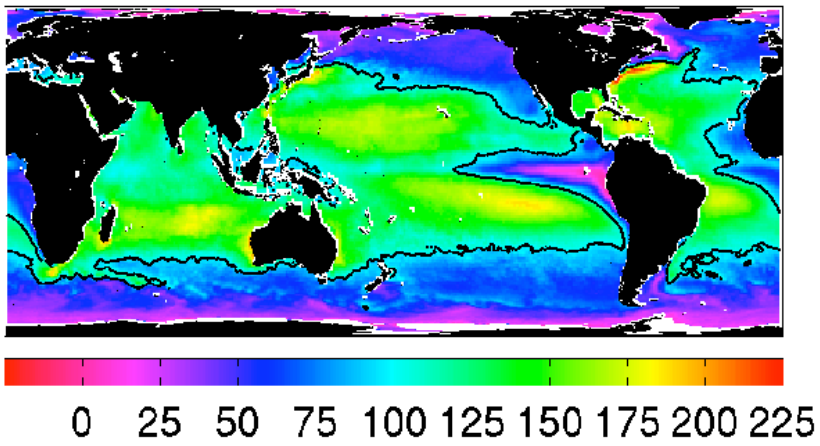
Seaflux v1 LHF



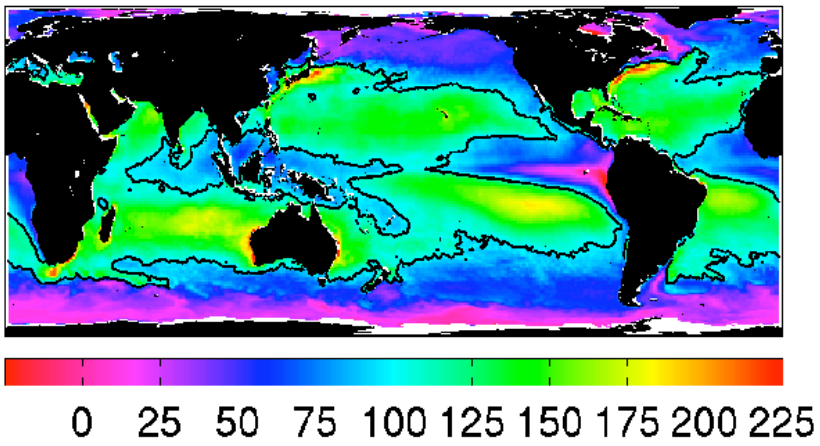
OAflux v3 LHF



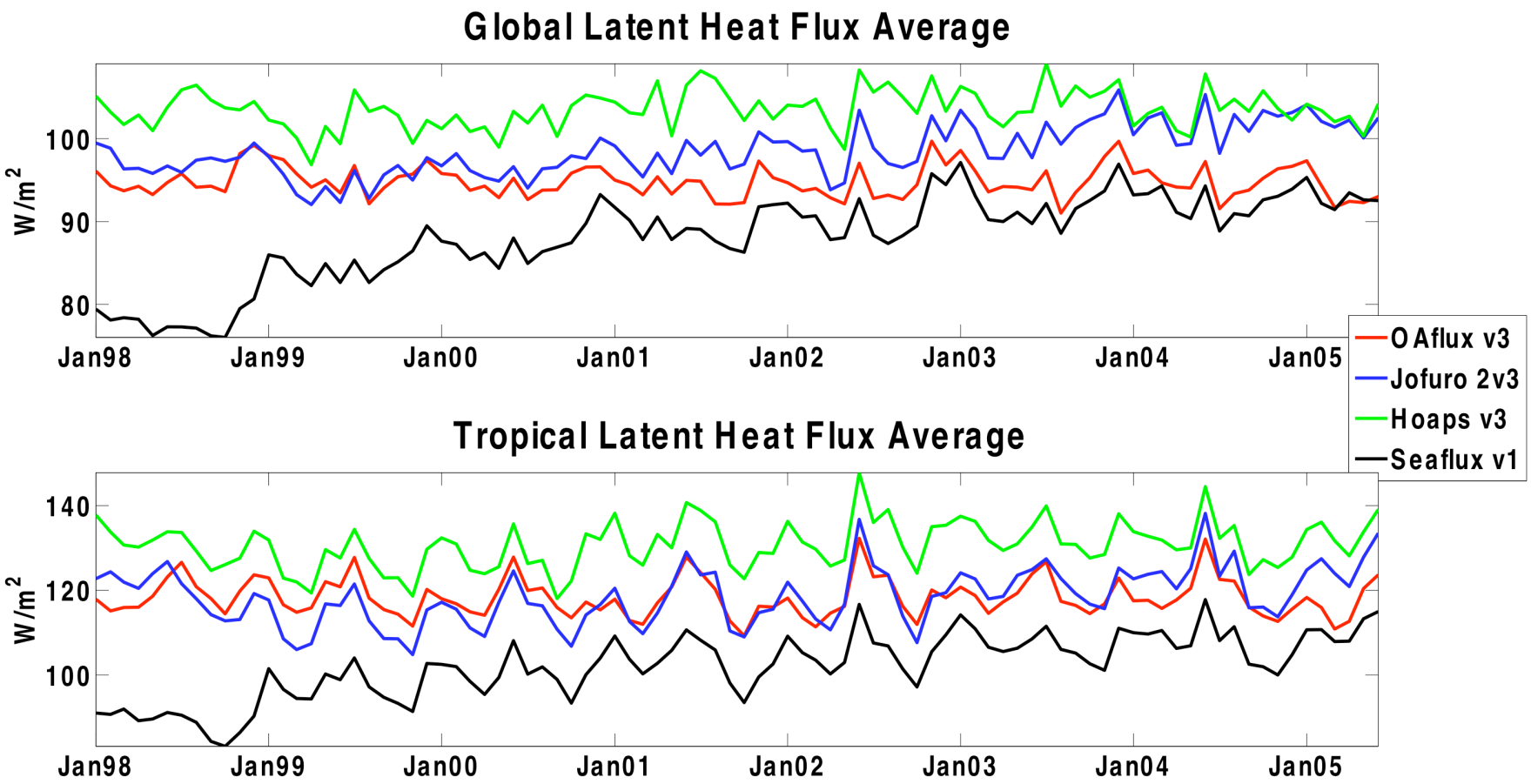
Hoaps v3 LHF



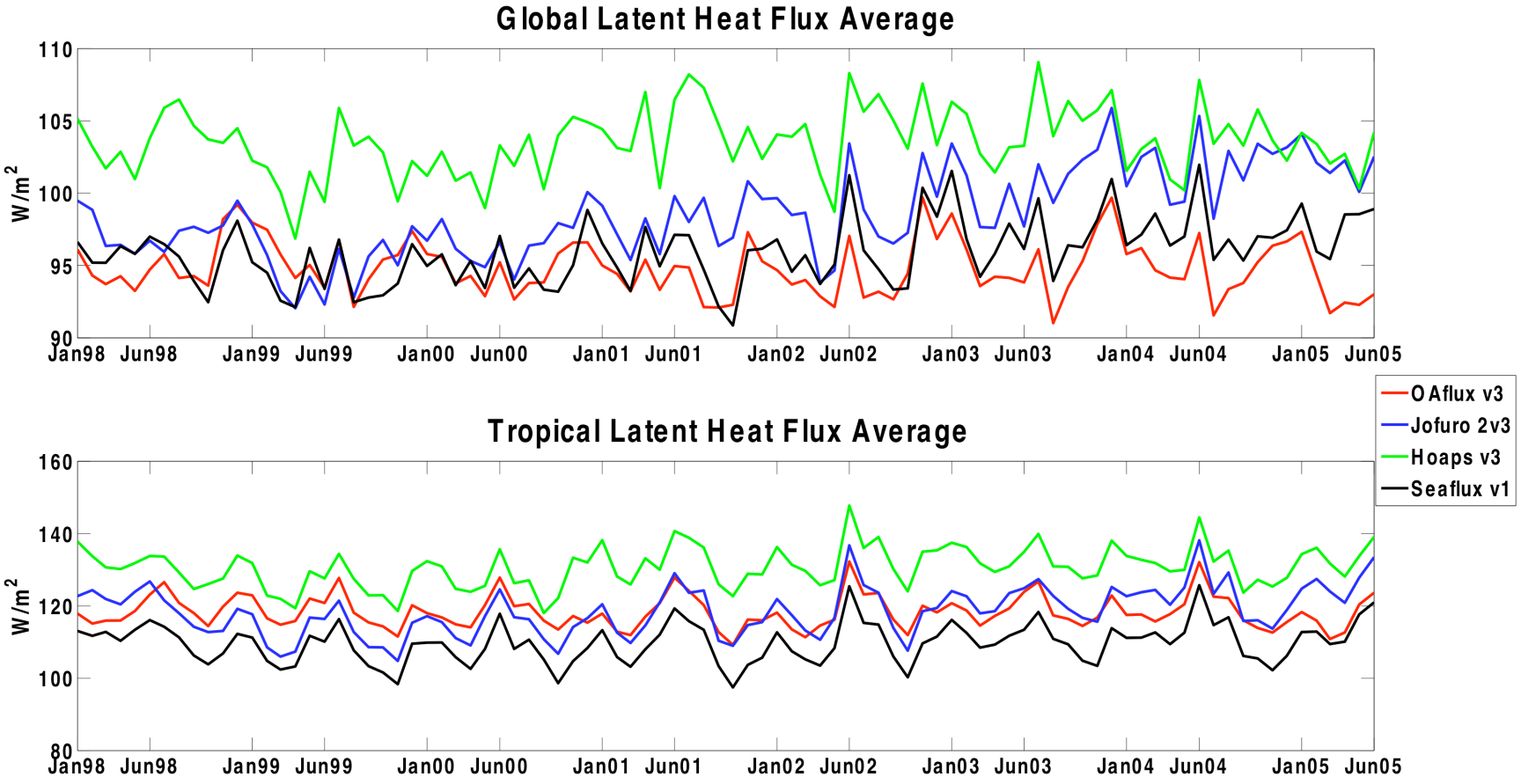
Jofuro v3 LHF



Trends in LH Flux – NN winds



Trends in LH Flux



- Initiated by GEWEX Radiation Panel (GRP, W. Rossow): parallel to “SeaFlux” project

- Workshop in Toulouse, May 2007
- Workshop in Melbourne, August 2009 (org: M. McCabe, S.I. Seneviratne, C. Jimenez, W. Rossow) ⇒ Overview paper in next GEWEX Newsletter

- Suggestion for activities
  - LandFlux-EVAL (S.I. Seneviratne, C. Jimenez) / initiated in 2009
  - New ET product (?) (M. McCabe, W. Rossow)

Measurements / estimates of ET

Ground observations

- Lysimeters; Flux towers (Fluxnet synthesis dataset)

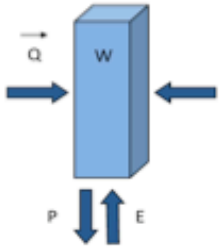
Satellite measurements

- Radiance-based ET estimates

Diagnostic estimates

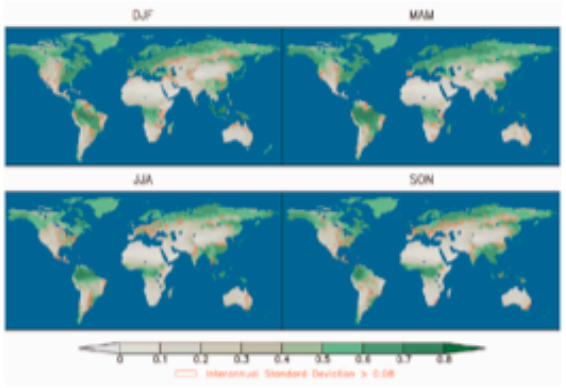
- Atmospheric water-balance estimates
  (Seneviratne et al. 2004, J. Climate; Hirschi et al. 2006, JHM;
  http://iacweb.ethz.ch/data/water_balance/)

$$E = \frac{\partial W}{\partial t} + \nabla_H \vec{Q} + P$$



Empirically-based estimates

- Fluxnet-based global ET dataset
  (Jung, Reichstein, et al., in prep.)



Model-data merging products

- Land surface models driven with observation-based forcing (GSWP, GLDAS, WATCH/WaterMIP)
- Reanalysis data products

1993-1995 analysis

Single-year (1993-1995) analyses (C. Jimenez et al.)

Preliminary inter-comparison of 1993-1995 monthly averaged land surface latent heat flux estimates

Carlos Jimenez
Catherine Prigent
Brigitte Muller
Sonia Seneviratne
Matthew McCabe
William Rossow

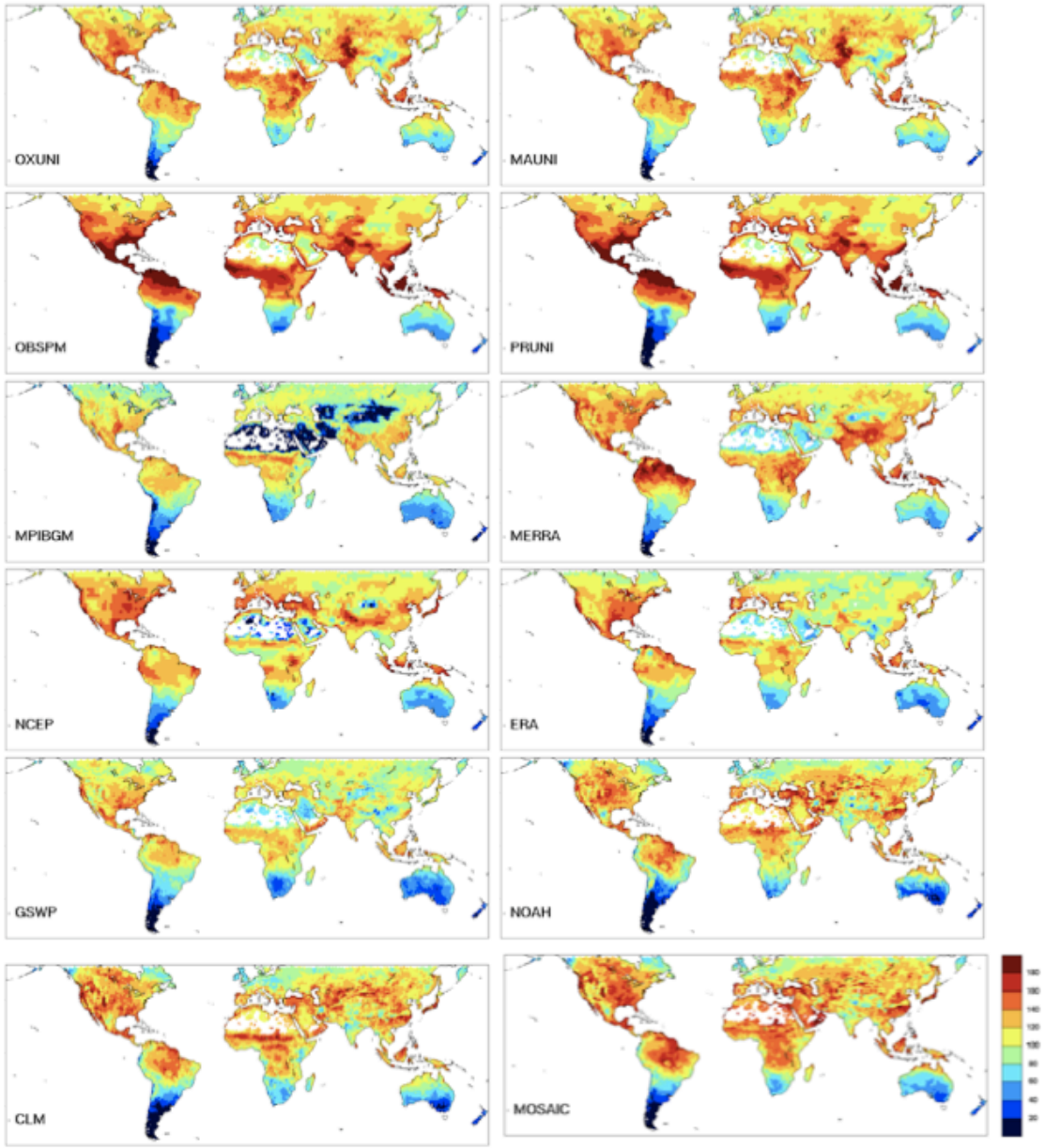
August 14, 2009

Considered datasets:

- Remote sensing products: U. Oxford (Fisher and Tu, "OXUNI"), U. Maryland (Wang et al., "MAUNI"), Paris Observatory (Jimenez et al., "OBSPM"), U. Princeton (Sheffield et al. "PRUNI")
- Empirical Fluxnet-based dataset (Jung, Reichstein, ...; MPI-BGC): Based on FaPAR data, CRU temperature, GPCC precip, land cover
- Land surface model output: GSWP average, ISBA (GSWP), WaterMIP average, JULES (WaterMIP)
- Reanalyses: MERRA (NASA/GSFC), NCEP-DOE, ERA-interim

Example of monthly Rn

- **Monthly averaged net radiation** (Rn)

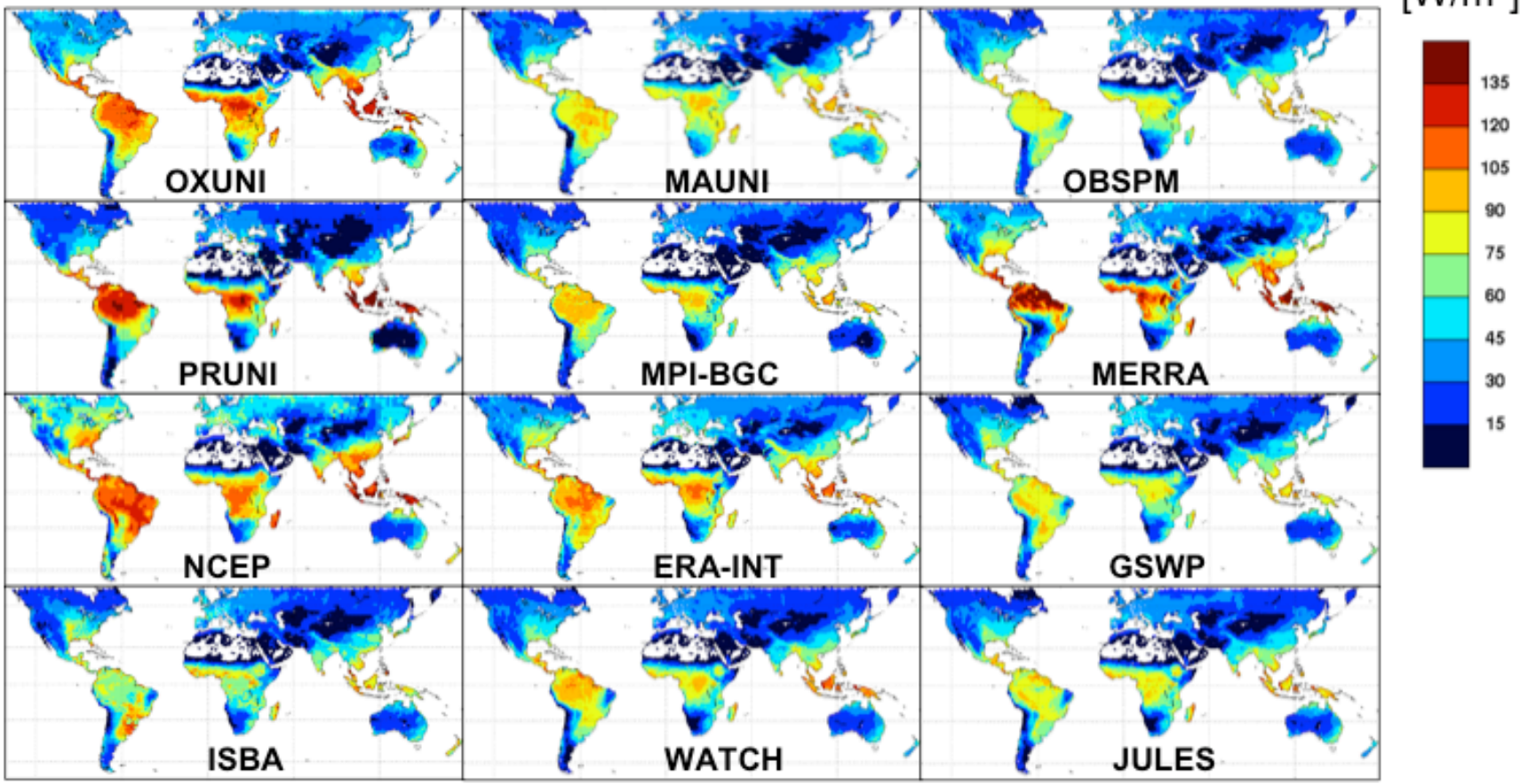


August 1993 [W/m^2]

Latent heating

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Global annual means (1993)

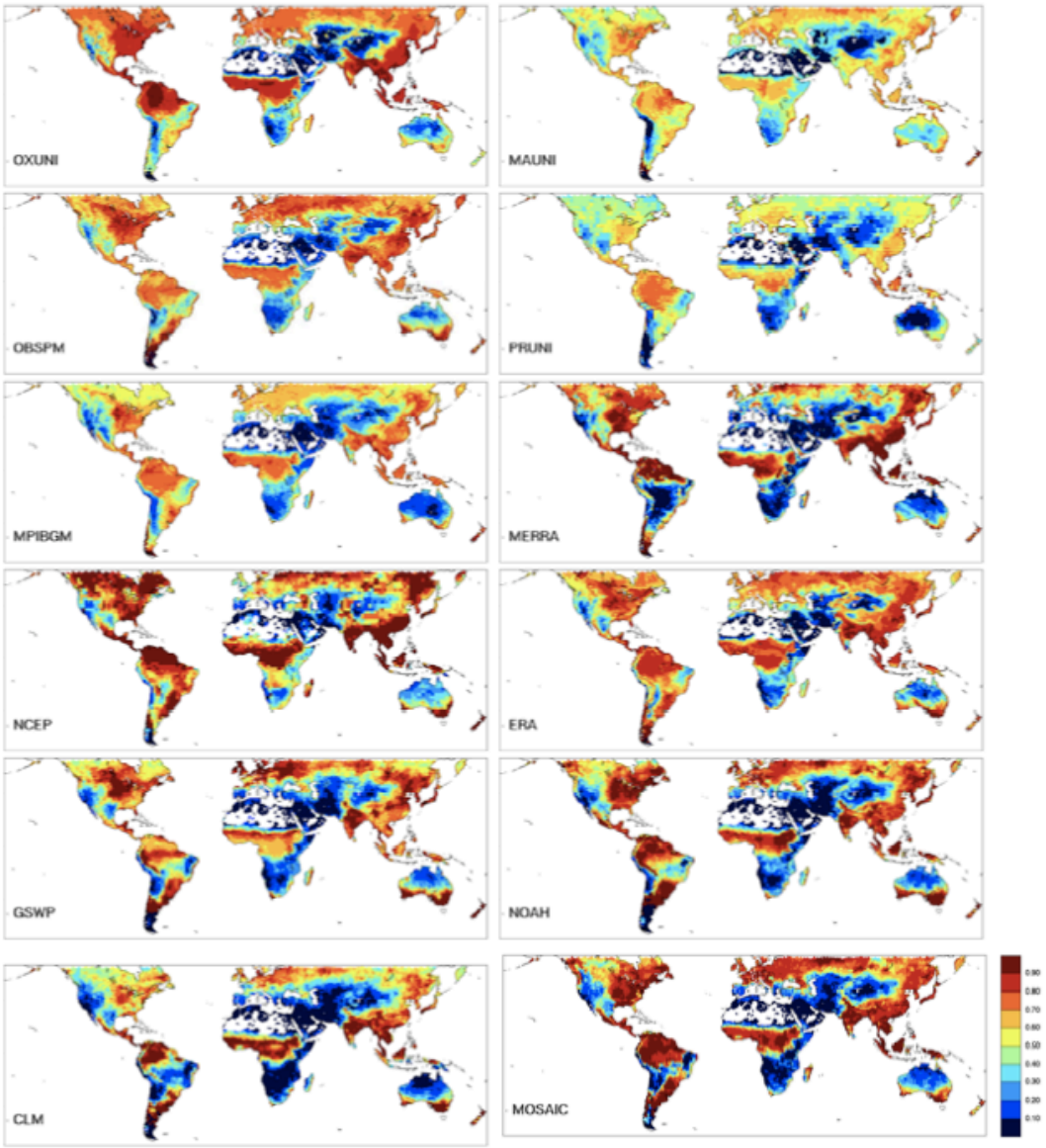


- Overall patterns look similar; dry - wet
- Some large range of values in some areas, in particular tropics

Example of monthly EF

- **Monthly averaged evaporative fraction** (EF)

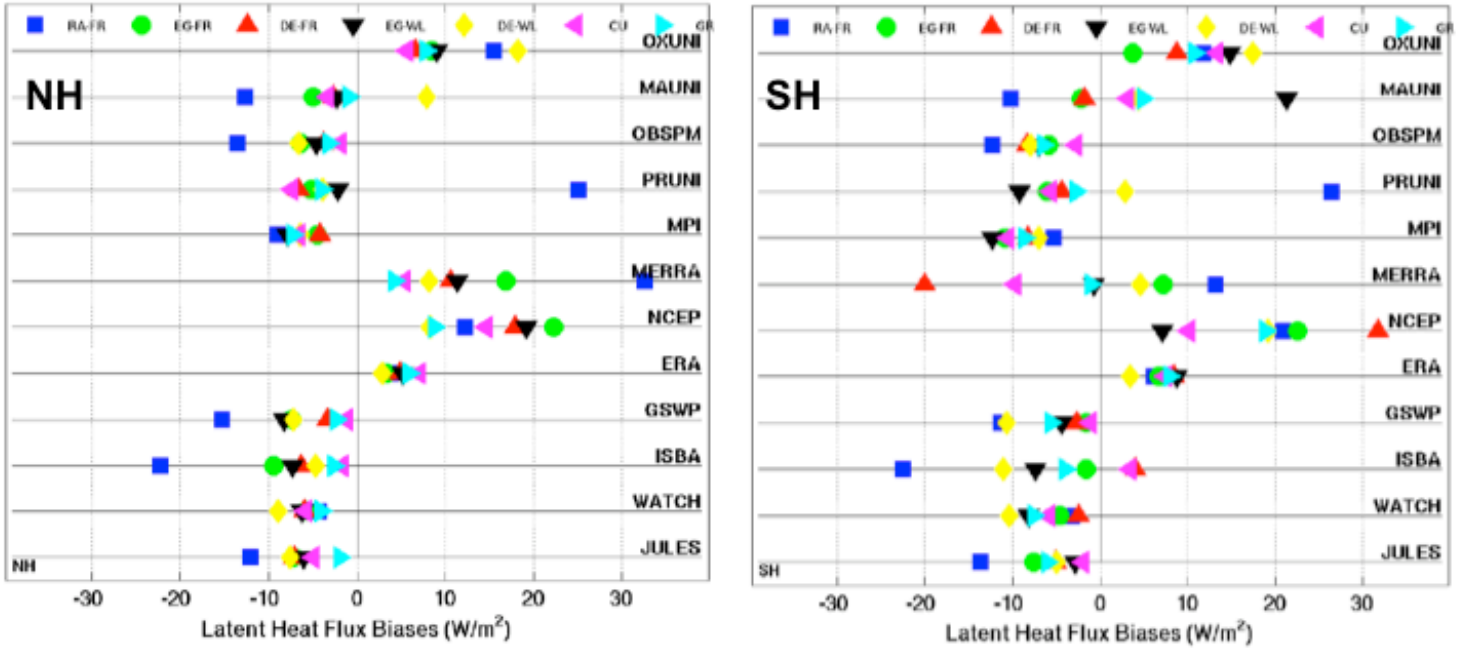
EF = LE / (LE+H)



August 1993 [W/m^2]

"Biases" to mean (1993)

Dependence on vegetation class



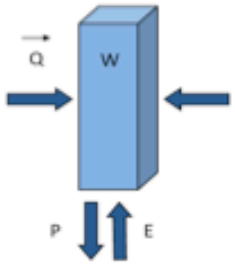
1993 heat flux biases for different vegetation classes. The biases are calculated with respect to the products ensemble average. Plotted the nothern (top) and southern (bottom) hemisphere biases. Class legends are: rain forest (RA-FR), evergreen forest (EG-FR), deciduous forest (DE-FR), evergreen woodland (EG-WL), deciduous wodland (DE-WL), cultivation (CU), and grassland (GR).

Multi-year (1989-1995/2006) analysis (B. Mueller et al.)

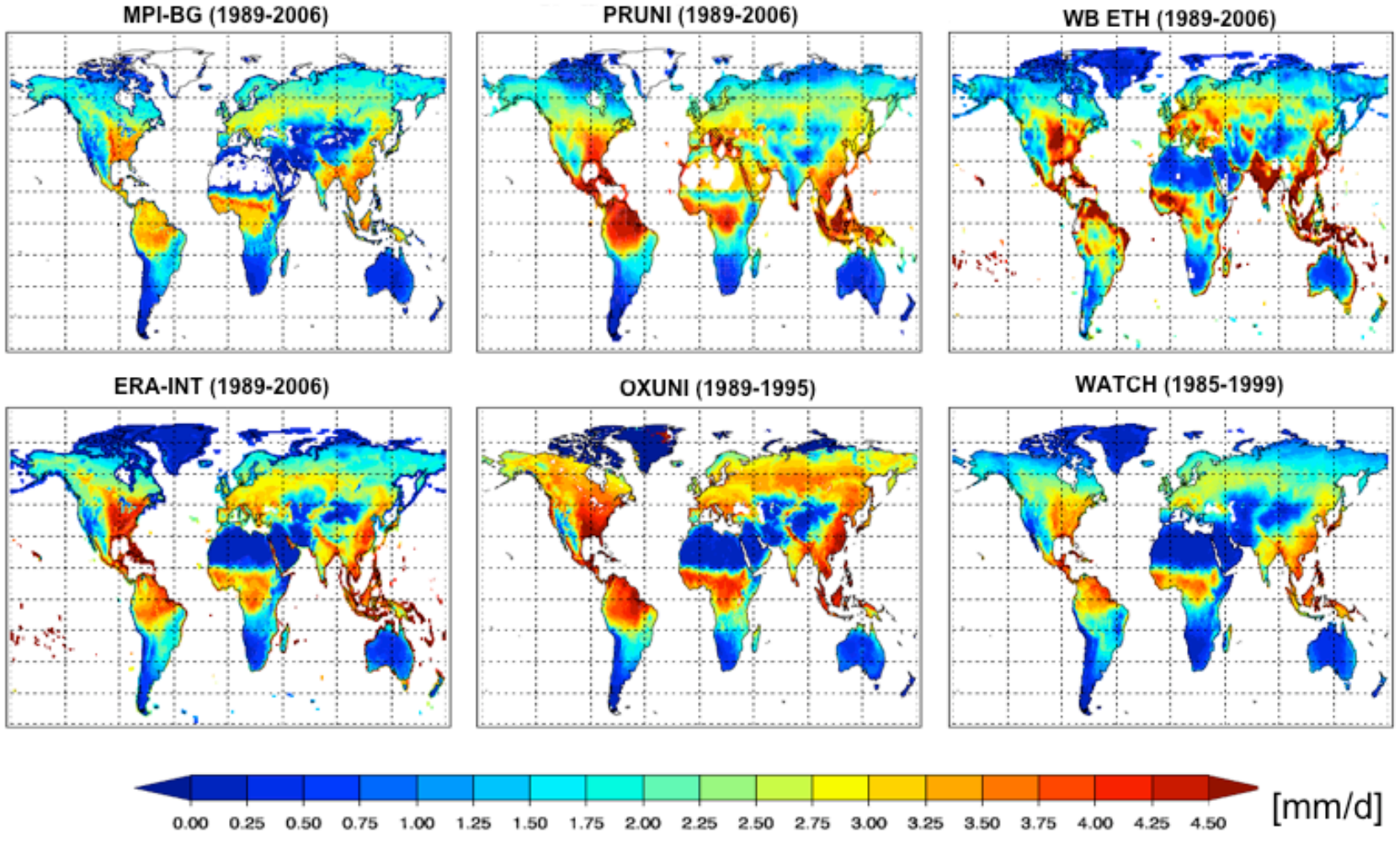
Considered datasets:

- Remote sensing products: U. Oxford (Fisher and Tu, "OXUNI"), U. Princeton (Sheffield et al. "PRUNI")
- Empirical Fluxnet-based dataset (Jung, Reichstein, ...; MPI-BGC): Based on FaPAR data, CRU temperature, GPCC precip, land cover
- Land surface model output: WaterMIP average
- Reanalysis product: ERA-interim
- Diagnostic estimates based on atmospheric water budgets (Mueller et al., ETH Zurich), based on divQ & dW/dt from ERA-interim and precip from GPCC
- *IPCC simulations: ECHAM5, GFDL, HadGEM1 (1982-2001)*

$$E = \frac{\partial W}{\partial t} + \nabla_H \vec{Q} + P$$



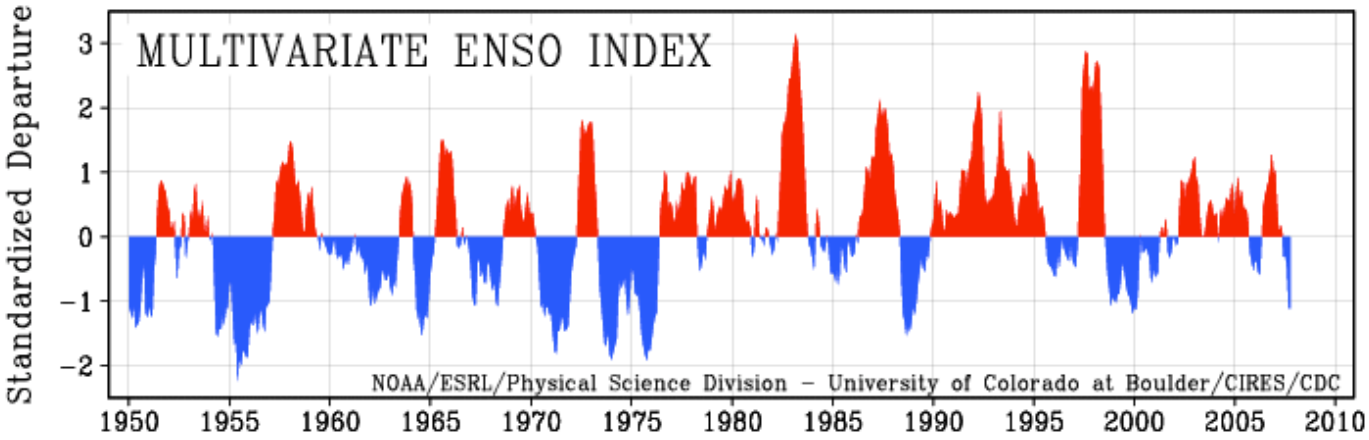
Multiyear analysis (JJA means)



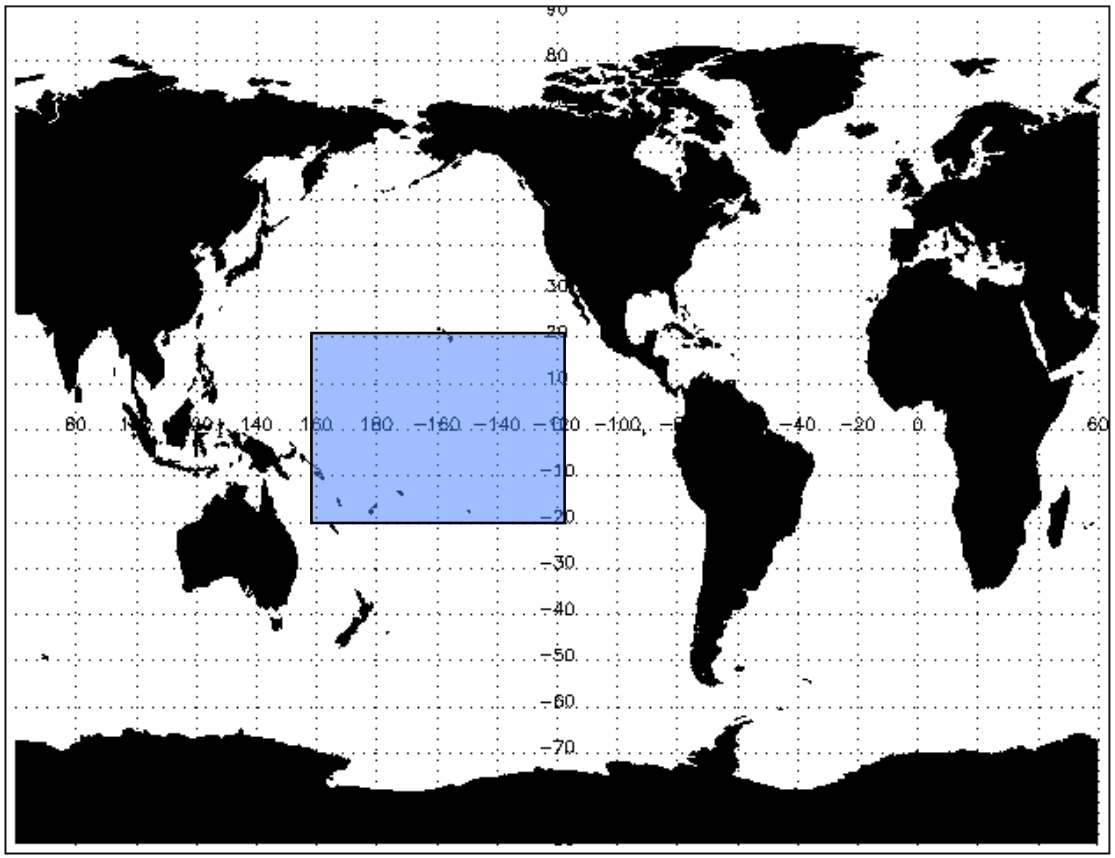
LandFlux-EVAL analysis: Outlook

- Evaluation will be extended to all IPCC simulations + additional products (reanalyses, land surface model output)
- Multi-decadal simulations (1900-2000) available from Global Carbon Project (Contacts with S. Sitch, Ph. Ciais): New simulations will be performed and suggested output variables will be taken into account
- Sheffield and Wood (1950-2000): VIC simulations
- "GSWP3"?: Workshop planned in June 2010 in Tokyo (Lead: T. Oki). Suggested joint workshop with LandFlux/LandFlux-EVAL workshop ?
- Consider as well sensible heat flux, runoff, soil moisture
- Data archive to be put together at ETH Zurich for data sharing among providers
- Planned Publications: Jimenez et al. (1993-1995), Mueller et al. (1989-2006), + additional paper on decadal trends & drivers of ET(GCP simulations, VIC)

An Example

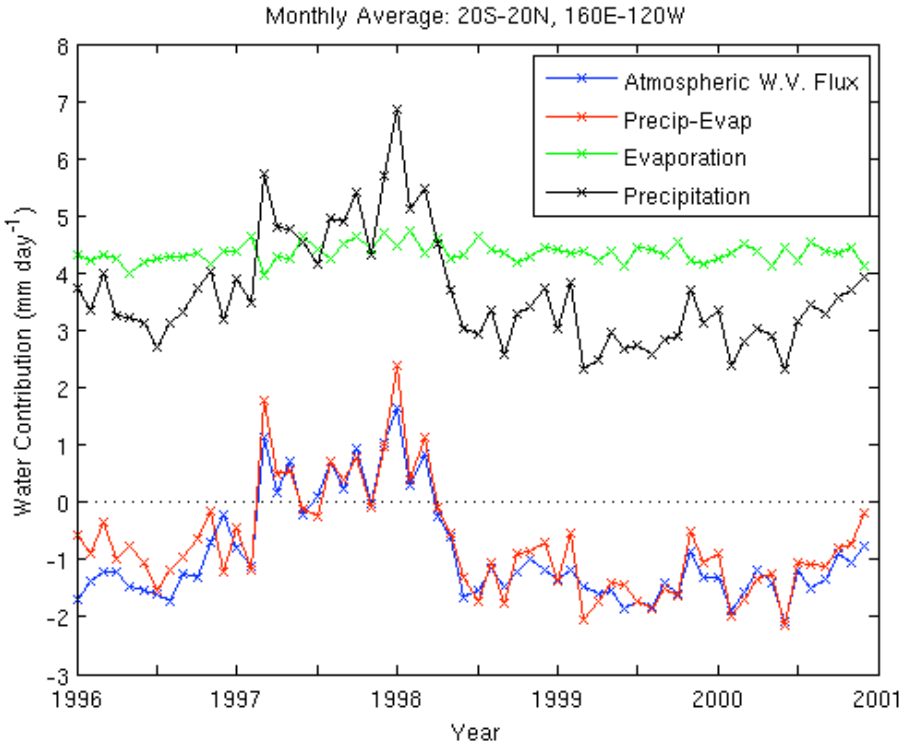


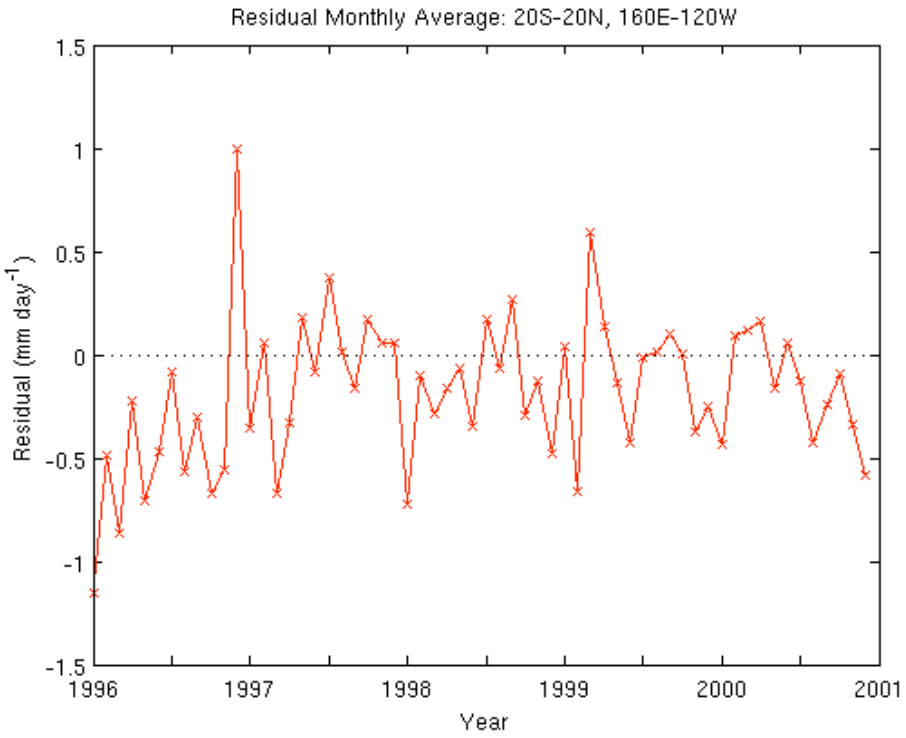
- Monthly means from 96 Jan through 00 Dec
- 20ºN-20ºS, 160ºE-120ºW



Water Budget

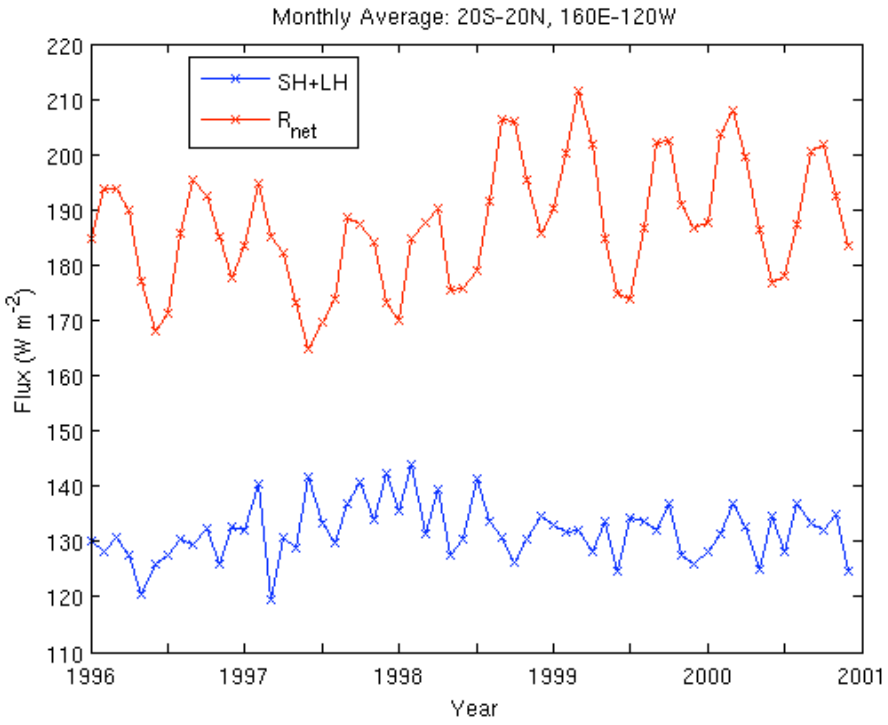
- Water Budget looks very close to being closed
  - Residual is always less than ~1.2 mm day^{-1}
  - Bias: -0.2 mm day^{-1} Std Dev: 0.4 mm day^{-1}

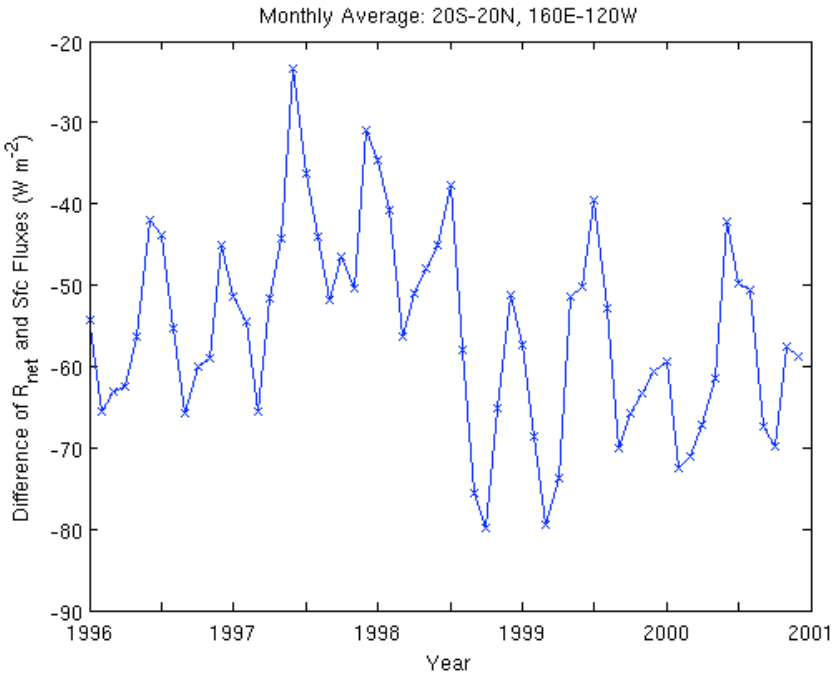




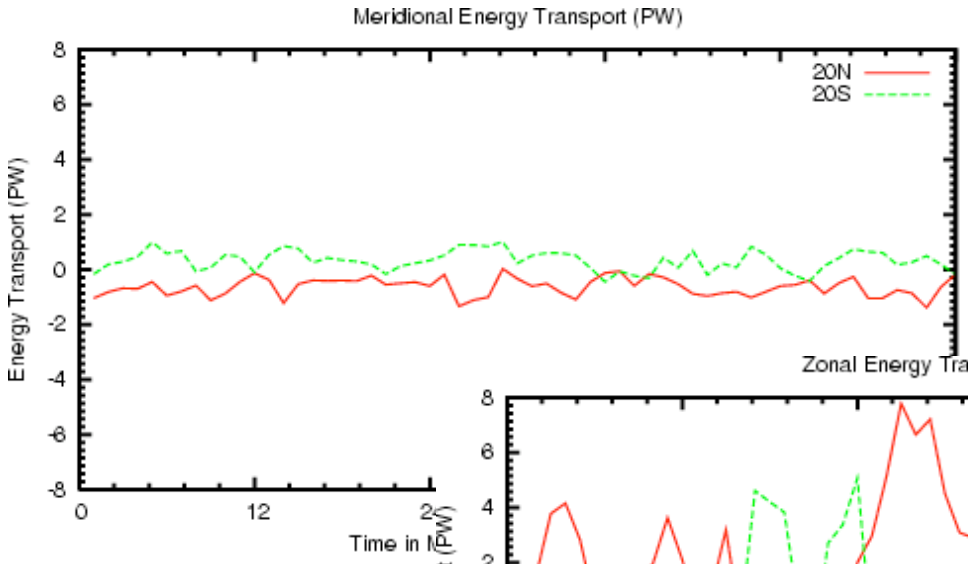
Surface Energy Balance

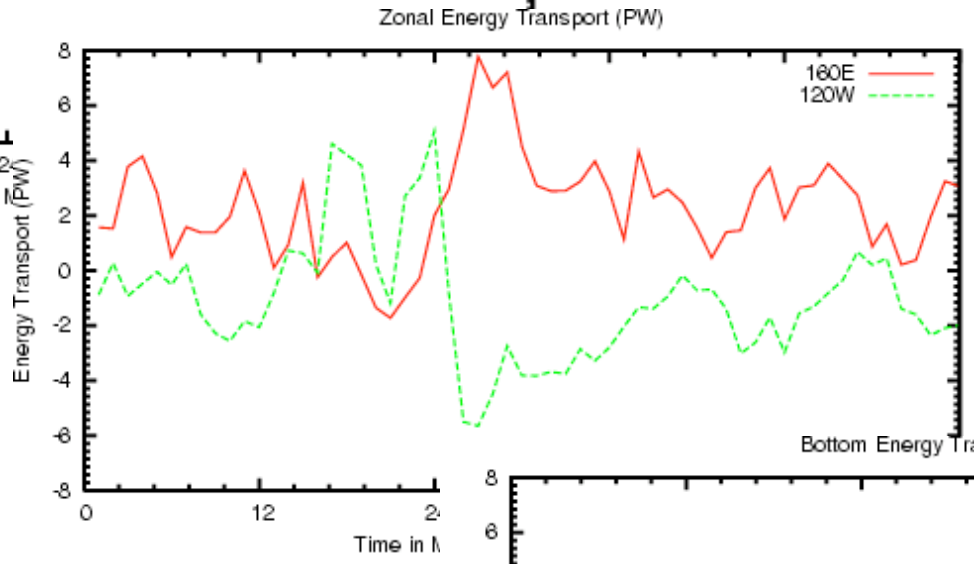
- Components: LH, SH, net surface radiation

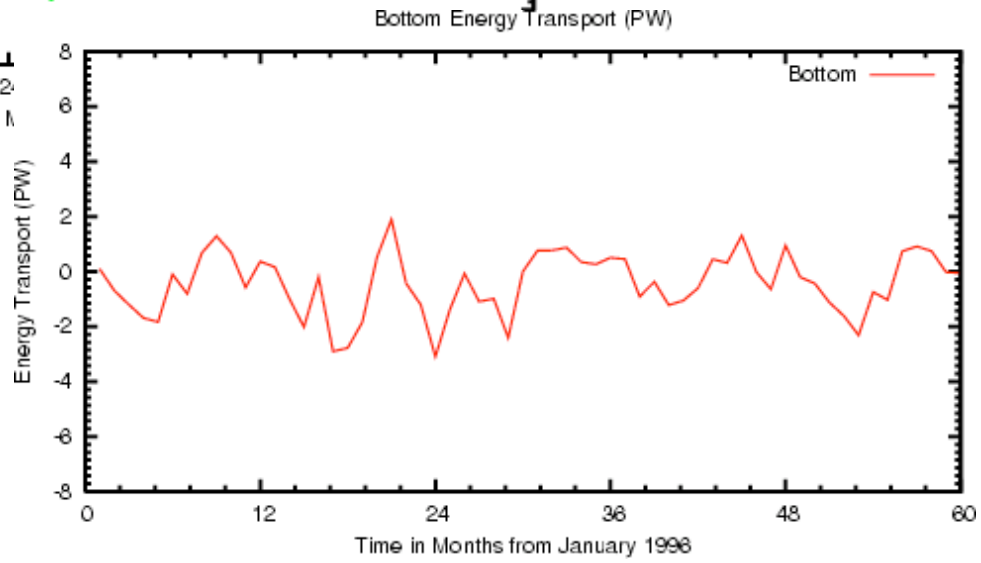




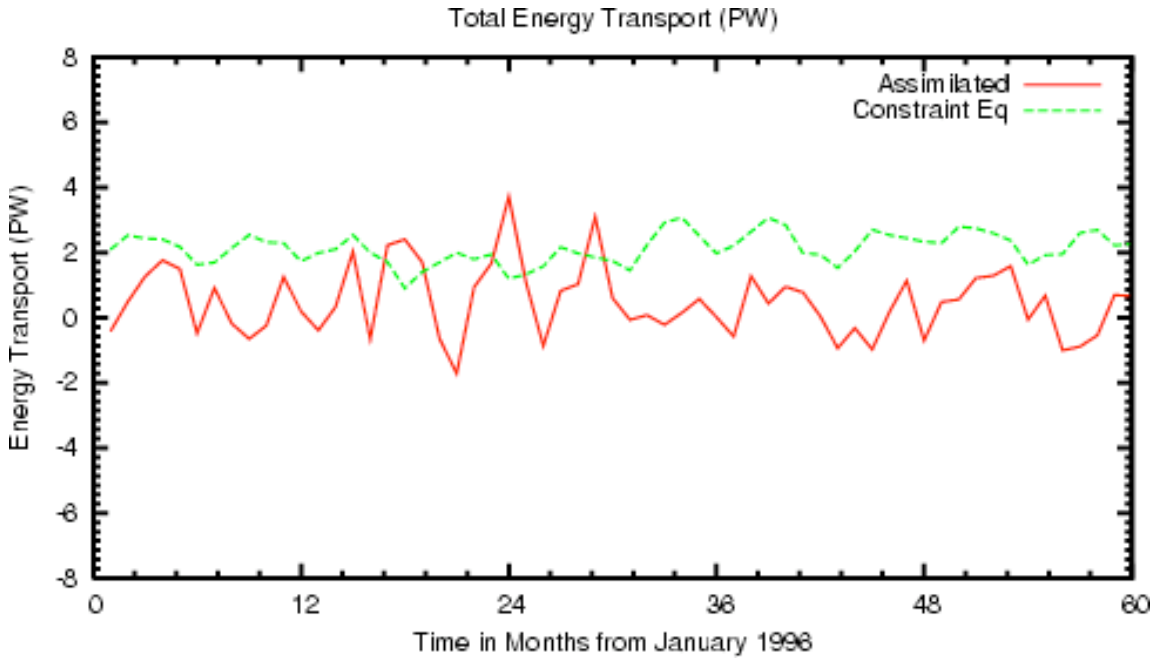
Ocean Energy Fluxes







Ocean Energy Fluxes



GRP Plan

- Provide a unified product of water and energy budget variables to community
  - Planned w. V3 of products (late 2010) w. common grid and ancillary data sets
  - NCDC plans to produce product from existing GEWEX data sets

- Use closure/lack thereof to improve products

- Use closure requirements to add to the GEWEX product set. Next product likely ocean heat content/transport from **Argo** buoys